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RMIT University

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PROVISIONAL SPECIFICATION

for the invention entitled:

"Cooling Garment"

The invention is described in the following statement:

COOLING GARMENT

The present invention relates to garments, and especially, clothing which is specifically adapted to provide thermoregulatory control. The garments in accordance with the invention provide active thermal control and in this respect are different from passive systems which function by means of insulation intended to retain body heat or to prevent adverse increase in body temperature due to the elevated temperature of the surroundings. The present invention is particularly concerned with garments for use by athletes to minimise heat stress and possibly enhance athletic performance. In accordance with the present invention this is achieved by pre-event, intra-event, inter-event and/or post-event cooling of the body.

Heat stress is the failure of the cooling mechanisms of the body to dissipate sufficient heat energy to normalise the body core temperature (about 37°C). Heat stress can lead to a reduction in reaction time, reduced energy/lethargy, attention deficit and muscle memory loss. This can lead to decreased efficiency, loss of functionality, decreased personal comfort and, at worst, reduced personal safety.

To optimise body function it is therefore important to maintain body temperature within safe levels during physical exertion, especially in high temperature environments. This is particularly important in sports where the athlete is likely to undergo some form of pre-event/match warm-up routine and/or be required to remain in a high temperature environment for a prolonged period, for example between events in track and field athletics. Indeed, research has shown that pre-cooling of the body before physical exertion can reduce athletic physiological strain in warm environments, thereby typically improving performance and/or minimising heat stress.

Numerous efforts have been made to adapt clothing in order to provide the wearer with a cooling effect. Much attention has focussed on phase change materials (PCMs) which function by changing physical state in response to temperature changes in the surrounding environment. When the external temperature rises above the melting point of a solid PCM,

the PCM melts by absorbing from the surroundings the necessary latent heat. On the other hand, when the ambient temperature falls below the melting temperature of a liquid PCM, solidification occurs with release of stored latent heat.

The ice to water phase change has been relied upon extensively to effect cooling during the melting process. However, in this case the body must also be adequately insulated form the ice in order to avoid discomfort and/or chilling. The need for insulation can add to the overall bulk and cost of a garment relying on this system. Ice is also inflexible and this can lead to the garments being cumbersome and uncomfortable to wear.

Inorganic salt hydrates are also commonly used. These tend to be cheap and exhibit favourable heat storage characteristics. However, the salts tend to segregate resulting in a reduction in active volume. Salt hydrates can also exhibit supercooling (delayed on-set of solidification) and tend to be corrosive to metals that are sometimes used in thermal storage systems.

Use has also been made of paraffins waxes, and the like. They tend to be chemically stable, exhibit little or no supercooling effect, are relatively safe and non-reactive. Their flammability may be reduced by suitable containment. However, conventional commercially available waxes tend to exhibit low thermal conductivity in the solid state and a broad temperature range over which the complete phase change is observed. The result is either very slow or incomplete phase change and poor sensitivity. High volume changes can also accompany the phase change and this can cause containment problems.

It is also known to microencapsulate PCMs into fibres, fabrics, foams and/or coated surfaces to impart thermoregulatory properties to textiles. However, the microcapsules tend to be small with the result that the thermal capacity of the PCM is relatively low. Water, such as perspiration, may become trapped within the bulk of the textile and this can also be to the detriment of the thermal capacity of the PCM.

Embodiments of the present invention seeks to address the problems described above. The

invention takes the form of a number of different embodiments. These embodiments may be employed independently or in any combination.

In one embodiment the invention resides in the use of a PCM which has been specifically formulated in order to have suitable thermoregulatory characteristics. According to this embodiment the invention provides an article of clothing comprising a PCM which is a blend of at least two compounds and which has a melting point of from 10 to 30°C and a melting temperature range of from 1 to 5°C.

Advantageously, the PCM used has a melting point of from 10 to 30°C. In the context of the present disclosure the term melting point is intended to denote the temperature at which the PCM begins to change phase. It will be appreciated that for a given solid material complete melting from a solid to a liquid does not take place at a single discrete temperature but over a temperature range. In accordance with the embodiment described this temperature range is from 1 to 5°C.

The fact that the PCM has a melting point of from 10 to 30°C means that it can be provided in close thermal relation with skin without the need for additional insulation to ensure comfort. This leads to an increase in overall thermal exchange efficiency and sensitivity. This also means that the article of clothing can be less bulky due to the absence of need of insulation.

The lower limit of this temperature range is selected because at lower melting points the article of clothing may feel uncomfortably cool, especially when the PCM is provided in close thermal relationship with the wearer's skin, as envisaged. The upper limit of this temperature range is selected because there needs to be a sufficiently large difference between the skin temperature of the wearer and the melting temperature of the PCM for efficient cooling. In general, the skin will be cooled provided that there is a temperature gradient favouring the flow of heat from it to the PCM. The temperature difference between the skin and the PCM should be sufficiently large to ensure rapid heat transfer. With a larger temperature gradient, less blood has to flow to the skin to achieve a given

degree of cooling. However, this tends to cause chilling. If the temperature of the PCM is too low, skin blood flow may be reduced to such an extent as to make transfer of heat from the body core to the skin inefficient and the body will attempt to retain heat. This which would be counterproductive.

The PCM chosen has a melting temperature (operating temperature) close to skin temperature and is thereby able to decrease skin temperature to below the normal 32°C. The result is a small but suitably significant decrease in core body temperature. The lowering of the core body temperature through heat uptake by the PCM is intended to reduce the occurrence of heat stress and, possibly, lead to an enhancement in athletic performance.

The PCM used in this embodiment has a melting temperature range of from 1 to 5°C. Desirably, melting of the PCM takes place over a very narrow temperature ranges as this ensures rapid heat absorption during PCM melting. The result is a rapid thermoregulatory response. Once the phase change to liquid has been completed effected, this also means that the PCM may be re-solidified rapidly, ready to be used again. This would be especially useful in situations where the article of clothing is worn for only a brief period and/or where the cooling ability of the article of clothing must be regenerated quickly by cooling. Preferably, the PCM has a melting point range of from 1 to 3°C.

Preferably, the melting point of the PCM is from 15 to 30°C, more preferably from about 20°C to 25°C. More preferably still, the melting temperature of the PCM is about 20°C. The preferred melting temperature and melting temperature range are intended to optimise the desirable characteristics of the PCM.

PCMs exhibiting suitable melting characteristics may be formulated by blending (at least two) compounds to provide the desired combination of properties and a significant aspect of the present invention is the tailoring of the PCM properties for the intended application, depending upon amongst other things, the extent of cooling required, for instance based on

the local temperature environment, the period for which the article of clothing is likely to be worn and/or the period over which the article of clothing is likely to be available for re-activation/regeneration of the cooling functionality.

The PCM usually comprises a mixture of alkanes (paraffins) typically having from 5 to 20 carbon atoms. The alkanes are usually predominantly (at least 95%) straight chain. Certain commercially available mixtures of such compounds will not include suitable proportions of constituents to achieve the PCM characteristics described. It may therefore be necessary to isolate particular fractions of the mixture in order to produce a PCM having suitable properties.

Typically, the mixture of n-alkanes is made up of compounds having a relatively low range of carbon number distribution. This is likely to result in a PCM having a suitably low melting point range. For example, the PCM may comprise a mixture of predominantly (at least 90%) C15-C20 n-alkanes. Preferably, the mixture comprises predominantly (at least 90%) C16-C18 n-alkanes. Fractions of alkanes (narrow cuts) may be isolated by selective removal techniques such as fractionation and by the use of selective adsorption, for instance using a molecular sieve. Alternatively, useful PCMs may be formulated by blending high purity n-alkanes which are commercially available. The proportions of the components may be adjusted as necessary to tailor the properties of the PCM. The intention in accordance with the invention is to use relatively small quantities of the PCM due to the enhanced efficiency of the PCM and the contribution of various other embodiments described herein.

Suitable PCMs comprising a mixture of n-alkanes and having the desired array of characteristics are also commercially available as such, for example, from Rubitherm under the designation RT20 and from Astorstat Thermostat. Waxes and high purity single n-alkane products (for formulation of the PCM by blending) are available from Haltermann Products, Alfa Aesar, Apratim International and Sigma Aldrich

Additional, preferred characteristics of the PCM include:

1. high heat storage to ensure the minimum possible amount of PCM is required to absorb the wearer's thermal load;
2. heat storage and release takes place at relatively constant temperature to ensure quick responsiveness to the wearer's skin temperature and a chilled atmosphere (on regeneration of cooling functionality) ;
3. low volume change during phase change so that suitable containment is not excessive resulting in surface area that cannot be used for heat transfer (e.g. less than 17 % expansion on complete melting)
4. high crystallinity to ensure good kinetic properties in the reversibility of the PCMs transition;
5. no significant supercooling- on PCM regeneration, it is necessary that all absorbed energy is released to the cooled atmosphere. When supercooling occurs, crystalline structures in a thermodynamically metastable state are formed, solidification of the melt occurs slowly, if at all, resulting in extended regeneration times;
6. ecologically safe and non-toxic; and
7. recyclable.

The PCM is usually provided in the article of clothing in the form of discrete packs or pouches. Conventional packaging systems and arrangements of the pouches in the article of clothing may be employed. However, another embodiment of the present invention relates to the way in which the PCM is encapsulated for use in the article of clothing.

As noted above, containment of PCMs can be problematic. This is because the material used for packaging the PCM must exhibit a number of beneficial properties. The material used must be sufficiently strong so that it is puncture, tear and rip resistant. Desirably the material is also flexible to maximise surface area contact with the surface to be cooled. The strength and flexibility of the material are also important properties in avoiding leakage due to volume expansion when the PCM changes state.

It is also desirable that the packaging material for the PCM is essentially inert to the PCM

contained and is neither corroded nor its properties significantly affected. Some PCMs are able to permeate certain layers, resulting in sweating of the PCM over prolonged use. Equally, the material should prevent ingress of external species, such as water vapour (in the form of sweat), into the body of the container and thus into the PCM. The material should also preferably be gas (e.g. O_2) impermeable as gas ingress can also adversely affect the PCM properties. It is also desirable that the material used for packaging the PCM may be suitably sealed to prevent PCM loss and aid manufacture. Preferably, the material used will be heat sealable.

The material must also exhibit suitable thermal transfer properties to maximise heat transfer across it and from the PCM. This will aid efficient cooling of a wearer in use and rapid re-generation of cooling ability when the PCM is chilled.

In accordance with the present invention it has been found that these desirable properties may be achieved using a laminate rather than a single layer of material. Thus, the present invention also provides a PCM encapsulated by a laminate film, wherein the laminate film comprises an outer heat-sealing layer and an inner layer which is impermeable to the PCM. Herein the terms "inner" and "outer" denote the relative position of the layers of the laminate relative to each other and the PCM. In the embodiment described the outer layer is remote to the PCM relative to the inner layer. Additional layers may be present however and the terms "inner" and "outer" are not intended to define the position of the layers in absolute terms.

In a preferred embodiment the laminate is a three-layer film comprising a layer which is impermeable to the PCM interposed between heat sealing layers. This arrangement offers more flexibility in manufacture of the encapsulated PCM because both outer layers of the laminate are heat-sealable.

In the embodiments described the materials chosen for each layer may individually or in combination provide desirable properties such as strength, puncture, tear and rip resistance and flexibility. The use of a laminate means that these properties need not be provided by

any one material. Obviously, the laminate itself should exhibit the desired level of flexibility and thermal conductivity and the material for each layer, and the thickness of each layer, will be selected accordingly. Desirably the overall thickness of the laminate is from 30 to 150μm, more preferably from 50 to 100μm.

A particularly preferred laminate for use with the kind of PCM defined above comprises a layer of (biaxially oriented) nylon interposed between layers of LLDPE. The nylon provides structural rigidity and imparts good chemical and abrasion resistance. The LLDPE offers water barrier properties and is heat-sealable. The nylon layer is typically from 10 to 50μm thick and the LLDPE layers from 50 to 100μm thick. Preferably, the nylon layer is about 15μm thick and each layer of LLDPE about 51μm thick. Such laminates are commercially available, for example from Cryovac under the designation RA463.

The encapsulated PCM is typically prepared by forming a pouch/pack of the laminate which is sealed around the edges and provided with a suitably sized unsealed section to allow the PCM to be inserted into the interior of the pouch. Usually the edges are heat sealed by conventional techniques. A pre-moulded block of the PCM of pre-determined volume (based on the volume capacity of the pouch) is inserted into the pouch and sealed in place by heat sealing. Air trapped within the pouch can cause insulation interference in the heat transfer process and sealing of the pouch is therefore preferably undertaken in a vacuum. The volume of (solid) PCM included in the pouch is calculated taking into account the volume capacity of the pouch when sealed and the volume expansion that the PCM will undergo on phase change. This is done to avoid rupturing of the pouch. A variety of configurations of encapsulated PCM may be prepared in this way. As will be explained below with particular reference to the figures, a number of pouches of different size are usually employed in a cooling garment in accordance with the present invention. For instance, the pouches may have approximate dimensions 110mm x 50mm (and having an internal volume capacity of about 50ml) and 75mm x 50mm (and having an internal volume capacity of about 30ml).

Another embodiment of the invention relates to the form in which the PCM is incorporated into a cooling garment. Conventional thinking suggests large volumes of PCM material should be included in large, continuous components. However, this can lead to the resulting garment being bulky and inflexible. Efforts to alleviate these problems have focussed on dividing large unitary components into segments/compartments which are joined by integral, flexible webbing. Efficiency of cooling is directly dependant on heat transfer from the body by conduction via skin contact and the use of numerous relatively small segments/compartments is intended to facilitate this. However, a further problem with the use of even this type of construction is that the materials used to contain the PCM (and which also form the webbing) are not water permeable and perspiration can accumulate on the body between the skin and the PCM-containing structure. This can lead to discomfort and detract from the overall efficiency of the cooling garment.

It has also been suggested to provide the PCM in pouches for insertion into suitably sized pockets provided in the garment. However, these pouches have also tended to be bulky and are not especially efficient. An embodiment of the present invention is based on the appreciation that a cooling garment may be prepared in which the PCM is contained in a number of individual and slender pouches which enable a flexible garment with good cooling efficiency to be prepared. The use of such pouches means that there will be numerous spaces between adjacent pouches and this can allow production of a breathable garment to be prepared, subject of course to selection of suitable material to occupy the spaces between the pouches.

In this embodiment the individual pouches are typically characterised as having a heat exchange surface area to volume ratio of from 1.06 to 1.10. For the entire garment (including any and all head/neck/chest/shoulder/back/sleeve portions), the heat exchange surface area to volume ratio is about1.78. In this context the volume referred to is actually the volume of PCM material included in the pouch. The surface area proximal the surface to be cooled (skin) should be as high as possible whilst bearing in mind that the resulting garment should retain high flexibility. Preferably the pouches take the form of elongate rectangular members, the dimensions of which may be varied depending upon the intended

location of member within the garment. It is also possible to manipulate the PCM loading and dimensions of the pouch in order to provide increased cooling efficiency over localised areas of the body where increase heat generation occurs, such as the head, chest, shoulder, neck and back. It is preferred to provide enhanced cooling to the shoulders and back due to the high heat loading observed at these locations during exercise.

If the PCM pouches are sized appropriately, it is possible to arrange the pouches over a large surface area of a garment whilst retaining adequate flexibility. The nature of the PCM encapsulation and the presence of spaces between adjacent pouches contribute to this. The pouches should be shaped in order to maintain optimal contact between the heat exchange surface of the pouch and the wearer's skin.

The PCM pouches may be inserted into pockets within the garment and sealed therein, either permanently for example by stitching or removably for example by fasteners such as zips and velcro. The material from which the garment is made is preferably lightweight and breathable, and shaped so that in use the PCM pouches will be in close proximity to the wearer's skin. The arrangement of PCM pouches should preferably afford the wearer ease of movement and offer a high level of comfort.

The PCM pouches are used in sufficient numbers to extend over a large area of the garment. It is desirable not to include any pouches at areas required to be flexible, such as elbow portions in a jacket, although suitably sized pouches may be arranged around such areas. It is also desirable to leave some gap between adjacent pouches to allow the garment to be breathable (as noted the textile used for the garment is preferably breathable). The pouches do exhibit a degree of flexibility and can be deformed (in use) to provide increased comfort. Fitting of the pouches to body contours in this way can also improve the efficiency of thermal transfer. The arrangement of pouches in an article of clothing is preferably designed by reference to infrared thermal imaging of the body of the intended wearer during pre-event, intra-event and/or post-event (cool down) periods, depending upon the intended use of the clothing.

The garment may take the form of a jacket, trousers, shorts, gloves etc, depending upon the intended field of use. Typically the garment will be a jacket with long sleeves, The jacket also preferably has a collar portion and/or removable hood. The sleeves of the jacket may also be removed. PCM pouches are usually fitted into all portions of the garment with particular attention on areas which in use are likely to come into proximity with body sites of high heat dissipation. Typically, the PCM material is concentrated in the garment to provide a high level of cooling to the chest, back and/or shoulder areas. The size of the pouch and thus the amount of PCM material contained may be varied accordingly. To aid flexibility the PCM pouches may be provided in a rib-like arrangement across the front and back of the garment (jacket in this case). The pouches should not extend over flex points, as noted. Regarding jacket design, the garment is compact and strategically laid out pouches allow a higher concentration of PCM loading than conventional ice jacket without compromising the mobility and comfort of the wearer.

The cooling garment in accordance with the present invention may comprise inner and outer shells. The inner shell is adapted to receive the PCM pouches in a suitable configuration to optimise cooling efficiency. The outer shell overlies the inner shell (and is usually attached thereto) and is intended to improve the overall aesthetic appearance of the garment as well as providing desirable functional properties such as wind and rain resistance. The inner shell may be formed of cotton wadding and the outer shell of a blend of natural and synthetic fibres such as nylon and cotton (available commercially as Coolmax Aquator, 51% nylon, 49% cotton). Desirably, both shells are lightweight. The outer shell may include surface decoration, motifs, advertisements, and the like.

Embodiments of the invention will now be described with reference to the accompanying non-limiting figures. The figures illustrate the arrangement of PCM pouches in component pieces of (the inner shell of) a jacket.

Figure 1 illustrates a back piece having PCM pouches of varying size attached. The PCM pouches are retained in pockets and extend across substantially the entire surface of the piece. The pouches are proved in a rib-like arrangement with small spaces between

adjacent pouches to allow the garment to breathe.

Figure 2 illustrates an arm piece (prior to stitching) and PCM pouches of varying size are positioned to ensure maximum contact with the wearer's skin when the sleeve portion is used in a jacket. Note that the PCM pouches are of smaller size at the "wrist end" of the sleeve (the top part of the piece in the figure). Note also that no PCM pouches are provided at the elbow point, where flexibility is required.

Figure 3 represents a front half piece. In the embodiment shown two half pieces will be fastenable, for example using a zip fastener. In another embodiment a single front piece may be used and in this case the jacket would be a pull-on type.

Figure 4 and 5 illustrate hood and collar pieces respectively.

Figures 6a and 6b are front and back views of a cooling jacket in accordance with the present invention. Figure 6a shows the outer shell of the jacket. Figure 6b shows the inner shell and includes PCM pouches in orientation similar to that shown in Figures 1 to 5. The inner and outer shells are essentially the same in shape and overall design, but this is not essential.

Figures 7 to 16 illustrate experimental results and are discussed in greater detail in the example included below.

The following non-limiting example illustrates an embodiment of the present invention.

Example

A cooling jacket in accordance with the present invention is prepared as follows. The jacket-like garment is composed of eight panels: the yoke section that covers the top back/front sections, the lower halves of the front and back section (2 left and 2 right sides), 2 long sleeve sections and a high collar. The exterior of the garment is essentially a casing

which in this example is Coolmax Aquator (51% nylon, 49% cotton, 240g in weight) and an interior primarily formed by cotton wadding (85g in weight).

Within the garment and next to the cotton wadding is located a series of pockets (inner shell) of wool/elastane (96.5%/3.5%, 230g). This fabric arrangement allows laminate pouches of the PCM to be inserted into this inner shell pockets whilst protection from ambient temperature is provided by the wadding insulation and the Coolmax outer shell. Ribbed cuffs and a bottom band ensure a close fit and protect from ambient warm air prematurely melting the PCM. These flexible heat-dissipating pouches are inserted into the channels from the side of each panel.

The pouches are formed from two heat-sealable transparent laminate sheets. In this example, laminate pouches of about 136μm thickness and of two sizes (11.6cm x 5cm and 7.6cm x 5cm) which were prepared by conventional 3-side heat sealing of two laminate sheets, leaving one side open. Premoulded blocks of PCM (Rubitherm RT20) of two sizes (7.5cm x 3.5cm x 3.0cm of volume 52ml (39g) and 3.5cm x 3.5cm x 3.0cm of volume 32ml (24g)) were inserted into the laminate pouches and the final seal was made using a vacuum heat sealing unit. Adequate volume was left within the pouch to accommodate volume expansion (about 16% on phase change of the RT20 product). When filled and remelted to obtain a flat-shaped compartment, the total thickness of the PCM pouch was about 1.5cm.

Placement of the laminate pouches within the garment is as shown in Figure 6b and more accurately (with regard to sizes of pouches) in Figures 1 to 5. Gaps (1cm in width) between the channels containing the filled laminate pouches and the small dimensions of the pouches themselves allows all panels to conform to the wearer's body to provide greater comfort, more freedom of movement and breathability when the garment is worn whilst still maintaining a close fit for efficient heat transfer.

The inner shell of fabric (wool elastane) was stitched to form parallel, diagonal channels of a specified width (between 5 and 6cm). In one example, ten such channels are formed on

each front and back panel. Figure 6b shows thirteen such channels on the front side of the jacket.

The two front panels are secured together via a zipper that extends along the entire length of the garment, from the bottom band up to the top of the collar. A close fitting hood with a PCM arrangement as per Figure 4, may be attached to the upper collar edge via a zipper, to allow heat transfer from the head and neck. The jacket in accordance with the invention weighed about 4.90kg without hood and about 5.50kg with hood.

The cooling jacket was evaluated in preliminary trials at the Australian Institute of Sport (Canberra) using two elite athletes (cyclists). Experiments were conducted with the athletes in an environmental chamber where ambient conditions of relative humidity (60-70%) and temperature (32.5-34°C) were controlled. One athlete (A) wore a conventional ice vest whilst the other (B) wore the jacket in accordance with the present invention to compare the effectiveness and impact of the new cooling garment on performance.

The ice vest had four large front pockets (2 top located breast-proximate pockets and 2 bottom located pockets) and four back pockets in similar positions to frontside locations. The pouch sizes were 14cm wide x 17cm long (top pouches) and 14cm wide x15cm long (bottom pouches). The pouches were made of a plastic film and filled with water to a volume capacity of 60% followed by freezing. An approximate volume of 2.5 litres of ice was used in the ice vest. The ice vest also included a thin layer of material on the inner surface of the vest to separate the ice packs from the skin surface. The total weight of the ice vest was about 3kg.

Three to four hours storage time in a freezer is deemed sufficient for regeneration of the ice-vest packs.

In contrast, the cooling jacket of the present invention required 0.5 hours for regeneration after usage (partial melting) in a pre-event application (after use for 0.5h with an athlete at rest). As for regeneration time in a 4°C atmosphere, two 11cm x 5cm laminate pouches

(containing 52ml of Rubitherm RT20) that were warmed until the contents completely melted were tested. One was placed in a pocket of the textile layers as assembled in the jacket and one was left to regenerate without insertion in a textile pocket. It was found that 90 minutes was sufficient for both pouch contents to solidify into a maleable (flexible) gel ready for re-use.

The two athletes (A and B) were studied over a 90 minute period over which three periods were defined: initial rest time (first 30 minutes, pre-cooling), 30-60 minutes (exercise period, cycle ergometer) and 60-90 minutes (recovery period, post-cooling). The garments were worn only during the pre-event and post-event periods.

Physiological responses such as skin surface temperatures (forearm, thigh, calf, chest), core body (rectal) and heart rate, sweat loss as well as thermal sensation and perceived exertion ratings were collected from each athlete. Temperature data was collected via infrared digital imaging and thermocouples.

Key improvements and enhancements resulting from wearing the jacket in accordance with the present invention are included in the following discussion. Circled points in the graphs refer to suspected measurement errors in the data collected.

- The jacket of the present invention showed a clear reduction in core body temperature (rectal temperature) during the exercise period by 1.1°C and that this cooling continues into the post exercise period (see Figure 7).
- Both cooling garments appreciably decrease chest temperatures, but this cooling effect extended in to the exercise period with a greater magnitude for the jacket of the invention (keeping temperature 2°C cooler than with no cooling) than for the ice vest (keeping temperature just 1°C cooler than with no cooling) (see Figure 8).
- The jacket of the invention reduced the forearm temperature by ~ 3.5°C whereas the ice vest managed to reduce this temperature by ~1°C. The greatest effect was felt in the first 10 minutes of the exercise period, where it took 20 minutes of

exercise for the temperature to reach the non-cooled forearm temperature (see Figure 9).

- Despite both jackets not covering the thighs, the thigh temperatures were significantly reduced for both garments with the new jacket prototype cooling the thighs by 1-2.4°C during initial pre cooling, 1-2°C over exercise period and by ~1°C during the post-exercise period. Corresponding reductions for the ice vest were lower, ~1.3°C cooling over the pre-exercise period, 0.75°C during the exercise period and by up to ~2°C over the post-exercise stage (see Figure 10).
- The heart rate was reduced significantly for both cooling garments in pre cooling periods, and moderately in the exercise period. The post-exercise heart rate reduction was greatest for the jacket of the invention prototype in the first 20 minutes of the post-exercise period and to exemplify, within the first 10 minutes of the post-exercise period the jacket of the invention reduced heart rate by 70bpm while the ice-vest reduced it by 55bpm. At 90 minutes, the total reduction in heart rate (from post exercise t = 0 to t=30min) was 98bpm for the jacket of the invention and just 70bpm for the ice vest (see Figure 11).
- Sweat loss was reduced by ~28-29% after use of either cooling jacket (see Figure 12).
- Ratings of perceived exertions were lower for both types of pre cooling jacket the reduction in exertion was less for ice-vest cooling than for the jacket of the invention. That is, athlete A reported a slightly larger difference in amounts of exertion with and without pre-cooling, i.e, pre cooling with the prototype caused a lowered rating of perceived exertion (see Figure 14).

The jacket in accordance with the present invention has been shown in this example to reduce the heart rate significantly, have a more enduring cooling effect in the post exercise period, provide significantly lower thigh temperatures despite not covering the legs, provide a lower thermal sensation rating (chilling), and provide a lower exertion rating with respect to no pre-cooling, compared to the conventional ice-cooling jacket.

Infrared digital imaging was used to quantify each athlete's skin temperatures during the

evaluation trials. Figures 15 and 16 show the athlete's skin temperatures for the jacket of the invention and the conventional ice vest respectively. Images are shown for the acclimatisation periods prior to exercise with and without the use of the cooling garments. Also included are images of each athlete after removal of the respective cooling garments.

The following scale relates the colour shown in the images to temperature

White---------Red------------yellow--------green------blue-----purple----------black
38°C----------37°C---------36.5°C-----36.3°C-----34-35°C------33°C -------- 32°C

Hyperthermia (hot)---Hypothermia (cold)

The significance of the R1-R3 pictures is that they show how the athlete's body is acclimatising to the conditions within the environmental chamber. Initially (in shots-R1 and R2), he is quite hot throughout his upper chest/shoulder, neck and head area as these areas are red. After a time, he cools down (R3), as demonstrated by the colour change (from red to yellow, green or orange) in the eyes, nose and upper chest areas. These pictures show the body adjusting to the humid/hot conditions without the aid of a cooling garment.

The most significant thing to note in comparing the thermal imaging is the difference in the head temperatures after using the cooling garments.

The conventional ice-vest does not cool the head appreciably (the head still stays red) while the jacket of the invention cools the head. Even after the vest/jacket has been removed, R6 and I6, only the cooling jacket of the invention allows the athlete's head to remain cooled (R6). The athlete wearing the ice-vest still has a hot head after the jacket has been removed (I6).

Also, both sets of images show the importance of reconfiguring the jacket of the invention so that we could increase the amount of cooling medium onto the upper back and shoulders to deal with the higher thermal of the body in these areas.

The greater reduction in skin temperature achieved by the jacket of the invention is consistent with the greater reduction in athlete core body temperature shown in Figure 7.

Dated this 18th day of July 2003

RMIT University

by DAVIES COLLISON CAVE
Patent Attorneys for the Applicant(s)

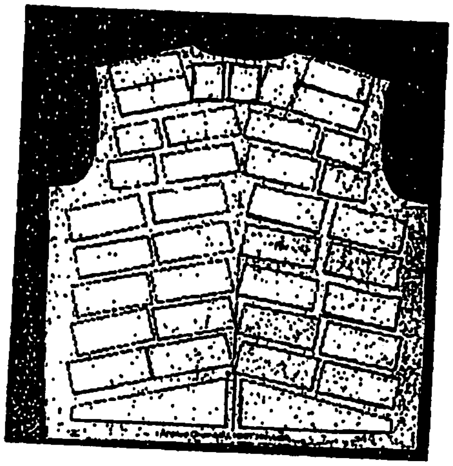


Figure 1

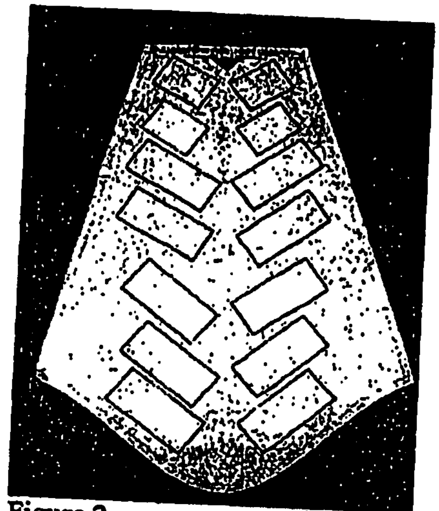


Figure 2

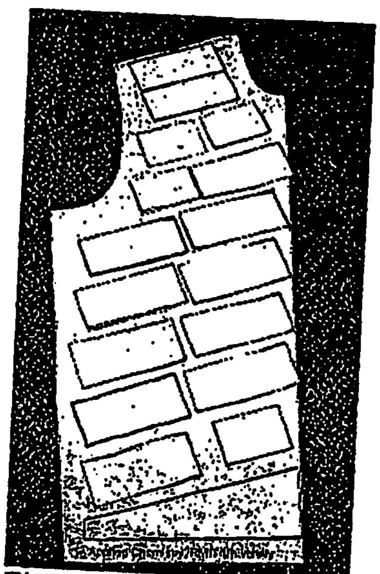


Figure 3

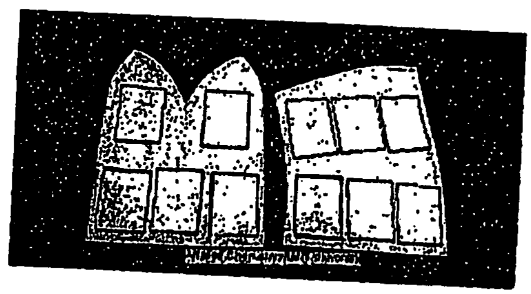


Figure 4

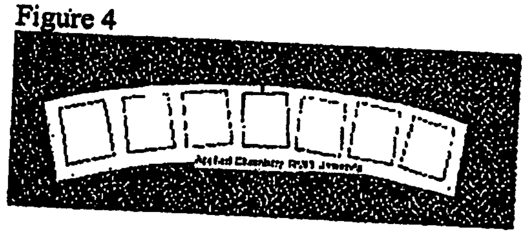


Figure 5

Figure 6a

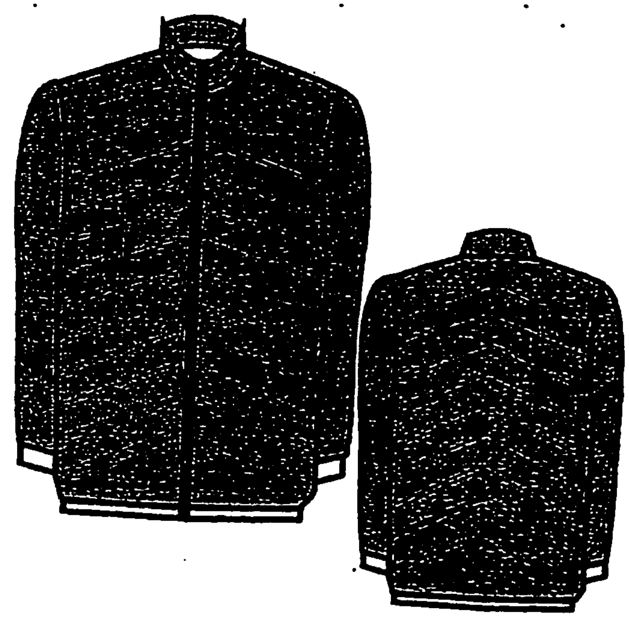
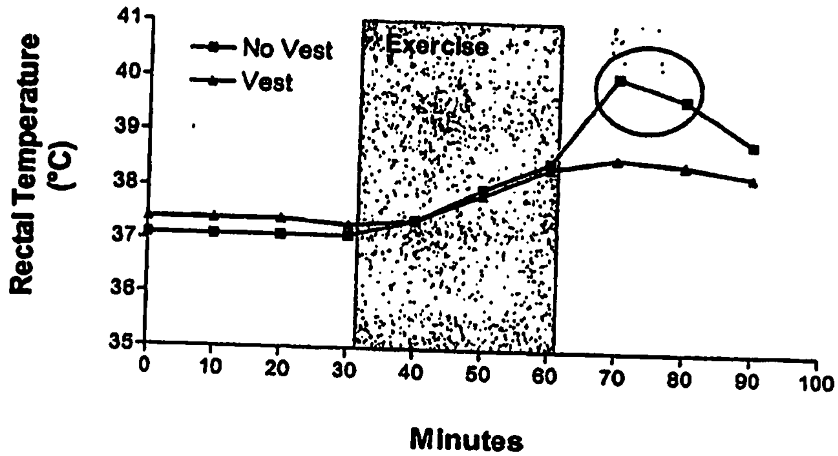


Figure 6b

A



B

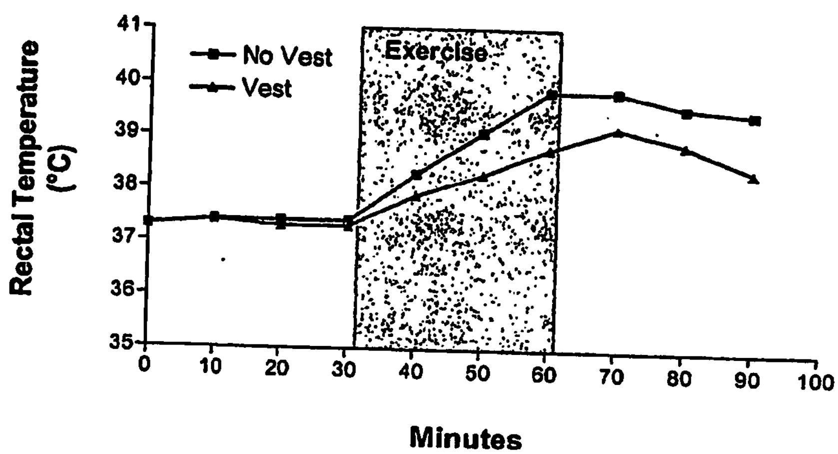


Figure 7: Rectal temperature measurements (core body temperature) over 90 minute study.

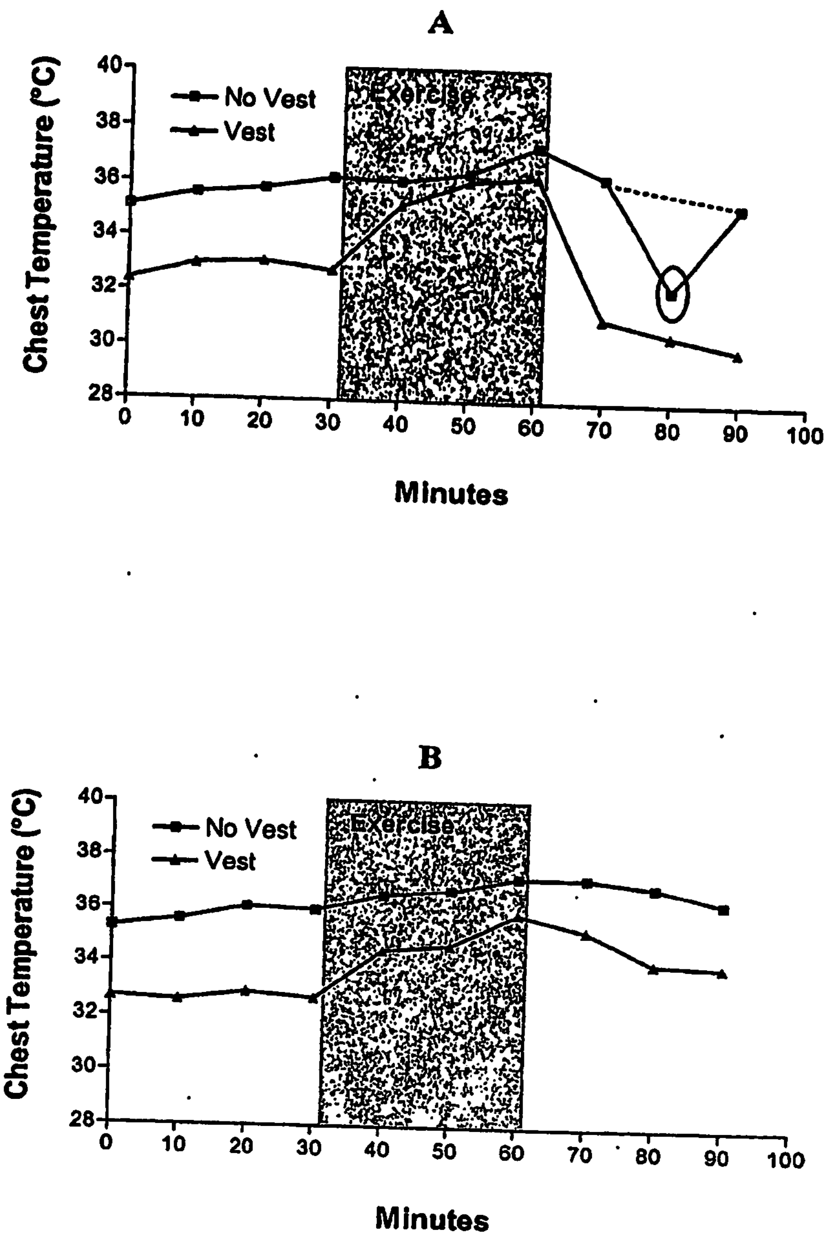
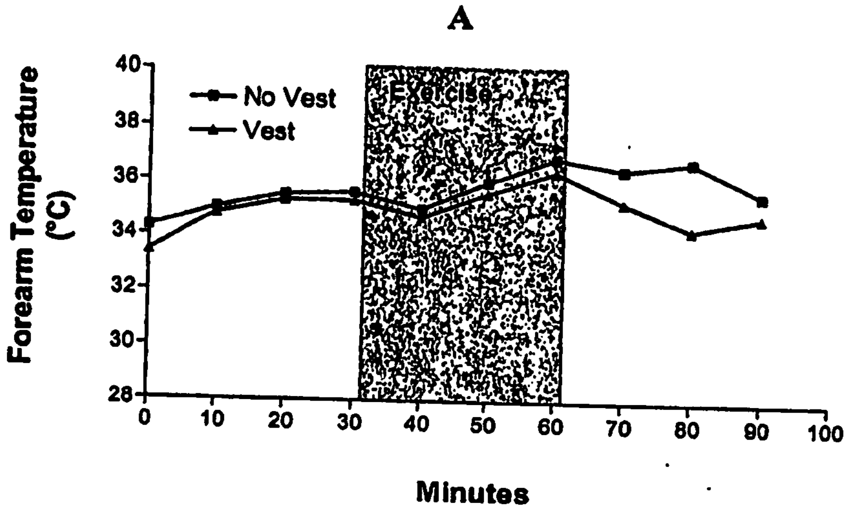


Figure 8: Chest temperature measurements over 90 minute study.



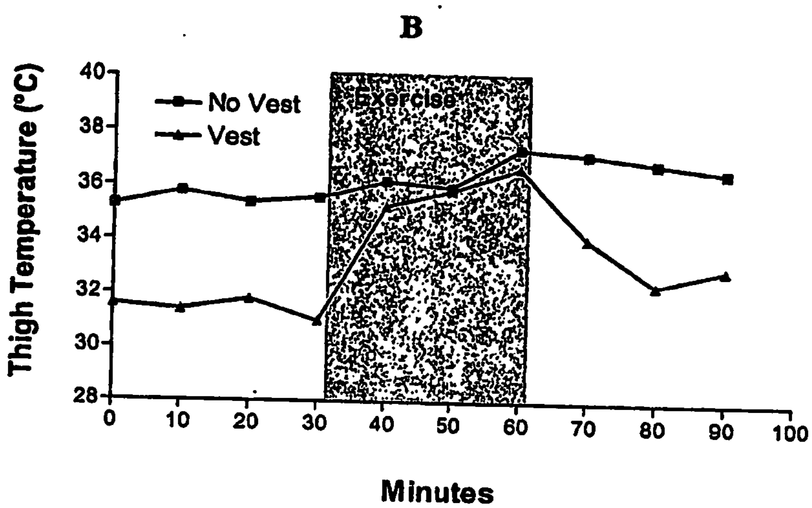


Figure 9- Forearm temperature measurements over 90 minute study.

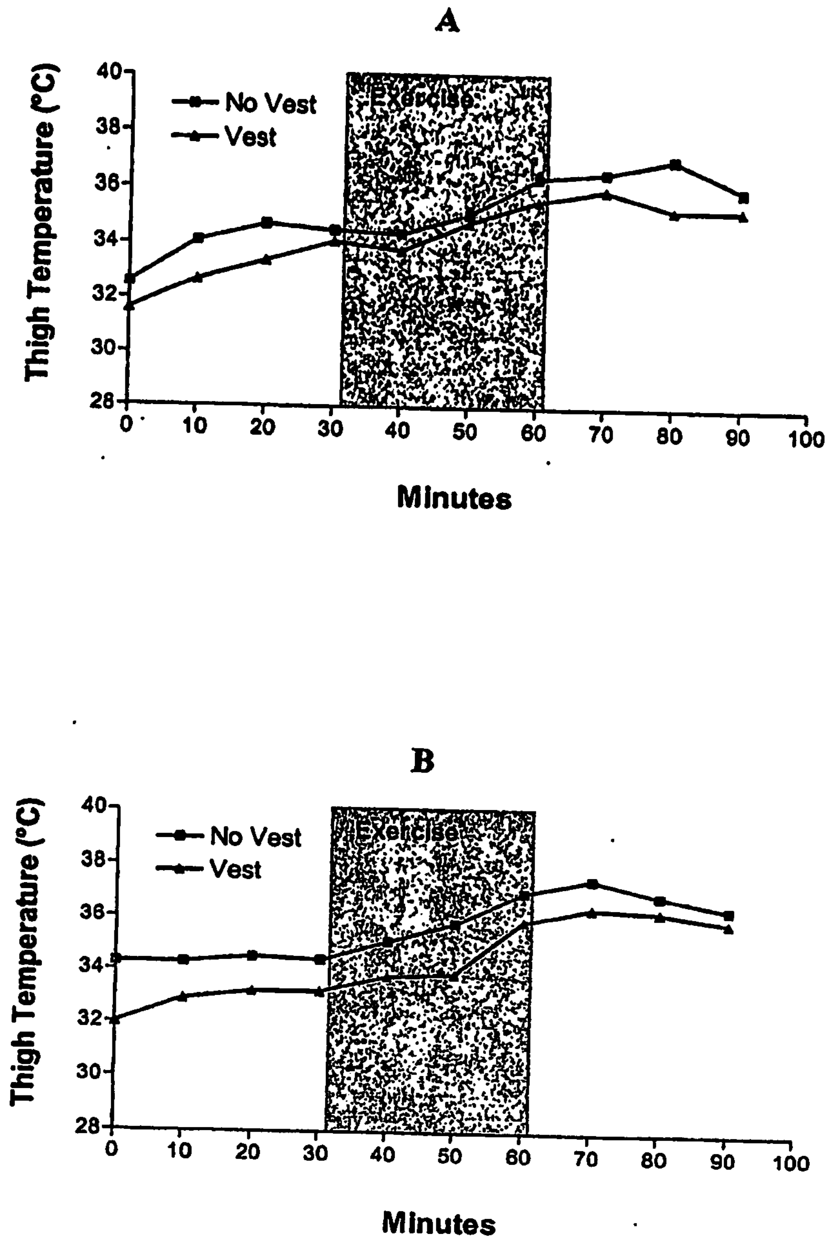


Figure 10: Thigh temperature measurements over 90 minute study.

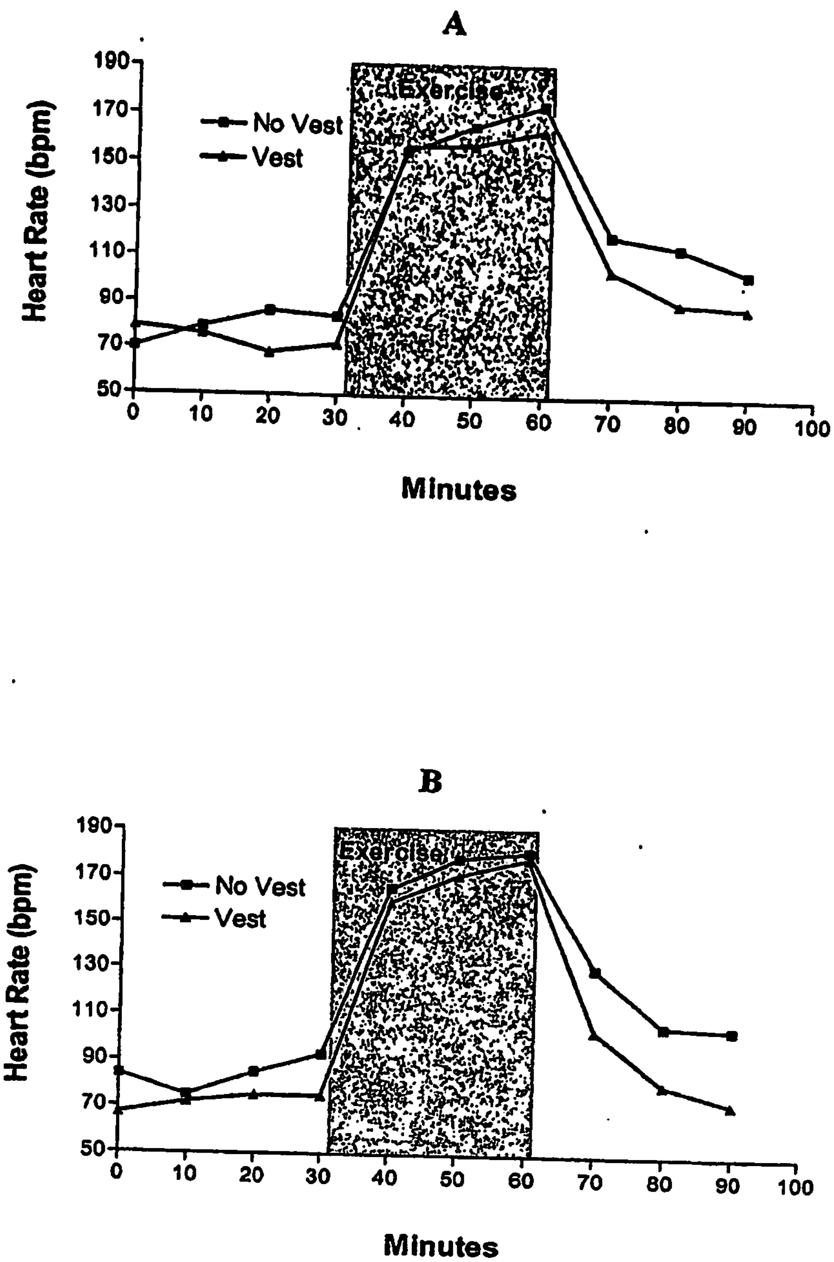


Figure 11: Heart Rate measurements over 90 minute study.

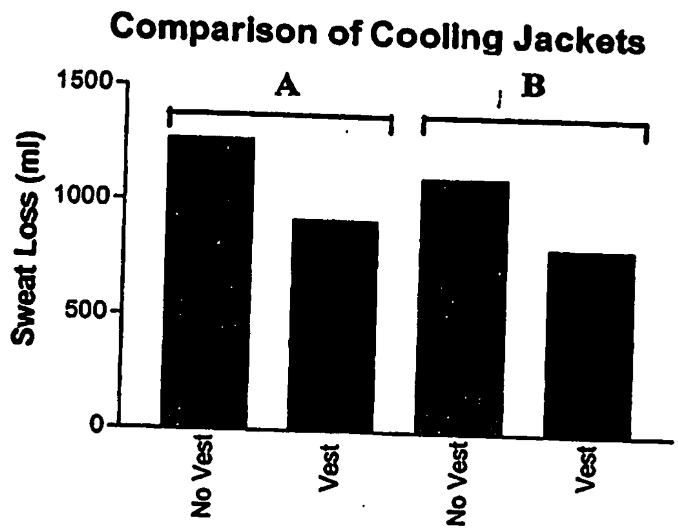
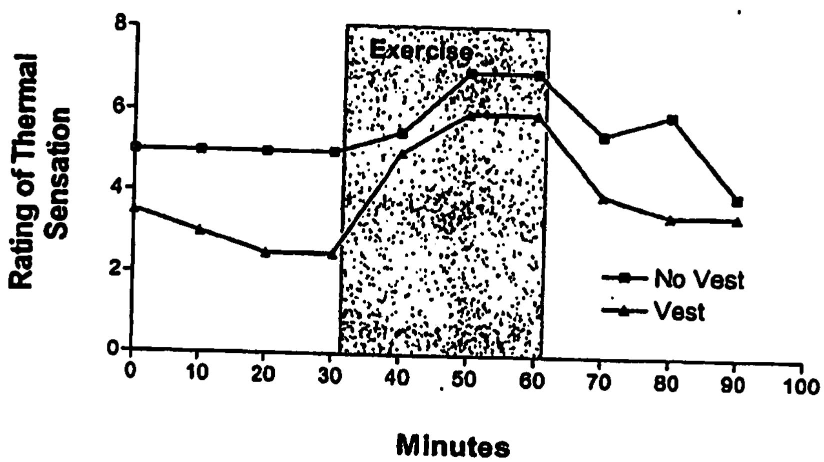


Figure 12: Sweat loss temperature over 90 minute study.

A



B

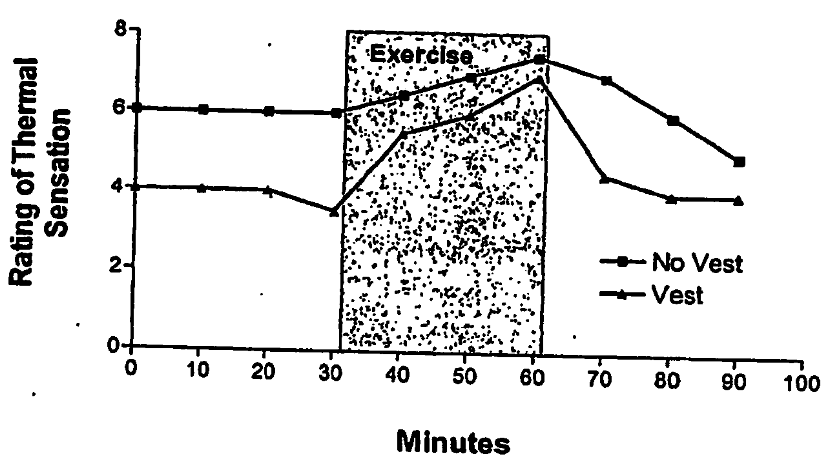
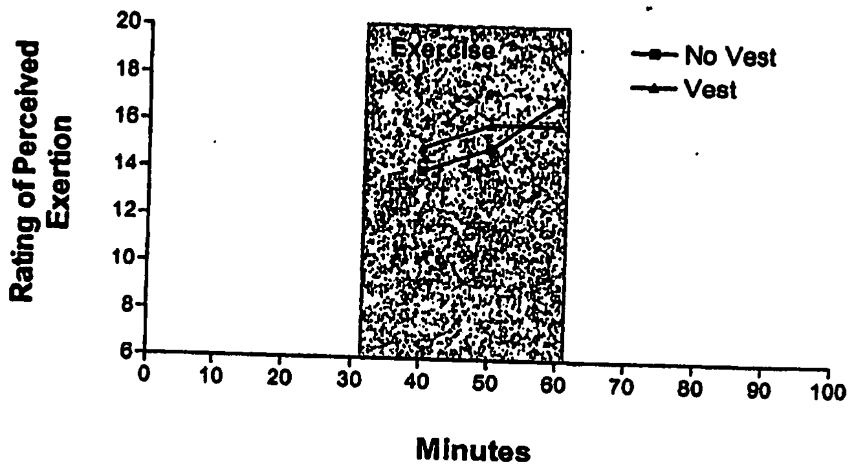


Figure 13: Rating of thermal sensation over 90 minute study.

A



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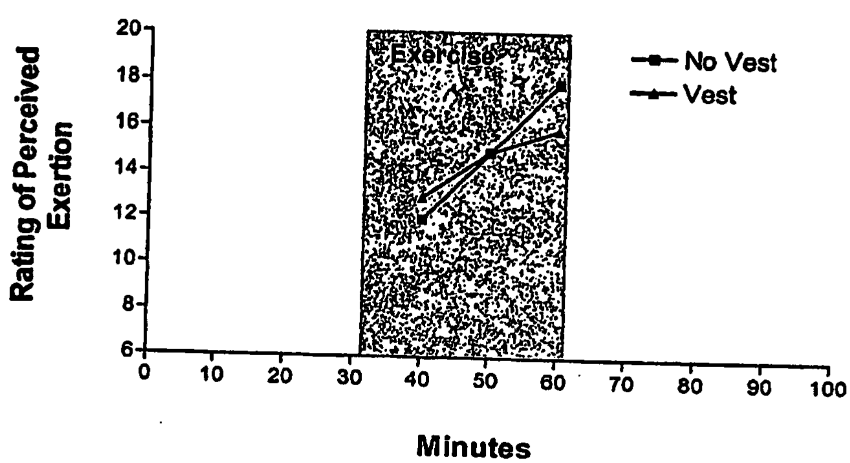
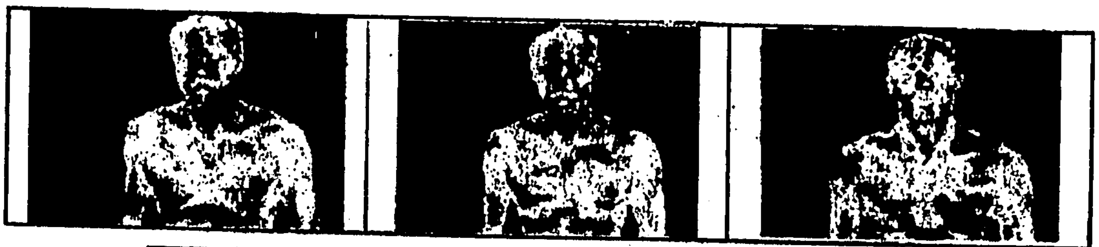


Figure 14: Rating of perceived exertion over 90 minute study.

Figure 15

Infrared Digital Imaging of Athlete Acclimatisation in High Temperature & Humidity Chamber Using the Jacket

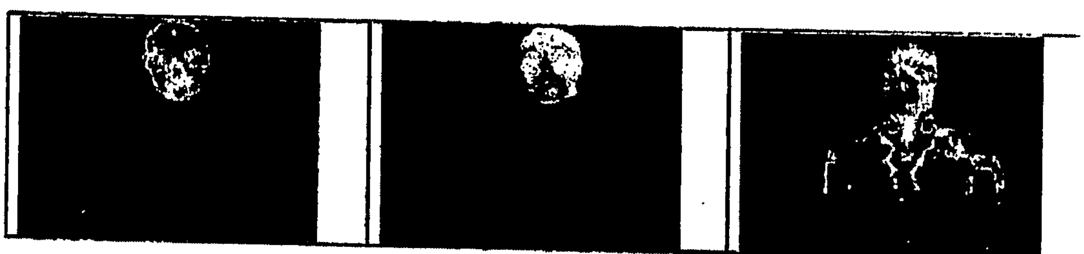
Acclimatisation without cooling jacket



R-1 R-2 R-3

R-1 to R-3 Acclimation prior to athlete exercise.

Acclimatisation with cooling jacket



R-4 R-5 R-6

R-4 to R-5 Acclimation with jacket prior to athlete exercise. R6 Athlete after removal of jacket during acclimation period

Figure 16

Infrared Digital Imaging of Athlete Acclimatisation in High Temperature & Humidity Using the ice-vest

Acclimatisation without ice-vest

I-1 I-2 I-3

I-1 to I-3 Acclimation prior to athlete exercise

Acclimatisation with ice-vest

I-4 I-5 I-6

I-4 to I-5 Acclimation with ice vest prior to athlete exercise. I-6 Athlete after removal of vest during acclimation period